destination is checked if it is available from any one of the middle switches MSi and MSj, and if both the middle switches MSi and MSj do not have availability for a particular destination, this particular pair of middle switches MSi and MSj cannot be used to set up the connection. However if middle switches MSi and MSj are determined to have unavailability of a particular destination, a different pair of middle switches are checked for example the middle switches MSi and MSk. In this implementation, middle switches MSi and MSk are checked for the availability of all the destinations of the connection 510 in the same manner as middle switches MSi and MSj. Therefore in this implementation, there is no need to use an additional array 540 of unavailable destinations from middle switch MSi (as discussed next).

An alternative implementation saves (see act 305 of FIG. 4C) an array 540 (see FIG. 4D) of unavailable destinations from middle switch MSi, at the time middle switch MSi is first paired with a middle switch, (e.g. MSj) other than itself when attempting to satisfy the connection request 510. Such saving of array 540 eliminates the need for each destination of the connection request 510 to be checked for middle switch MSi, when middle switch MSi is paired with another middle switch (e.g. MSk). If the array 540 of unavailable destinations from MSi is saved once, only these destinations (in array 540) need to be checked for availability in middle switch MSk, which improves the speed of the computation. The embodiment of FIG. 4D can be implemented to set up connections in a controller and memory (described above in reference to FIG. 1A, FIG. 2A, and FIG. 2B etc.).

In rearrangeably nonblocking networks, the switch hardware cost is reduced at the expense of increasing the time required to set up connection a connection. The set up time is increased in a rearrangeably nonblocking network because existing connections that are disrupted to implement rearrangement need to be themselves set up, in addition to the new connection. For this reason, it is desirable to minimize or even eliminate the need for rearrangements to existing connections when setting up a new connection. When the need for rearrangement is eliminated, that network is either wide-sense nonblocking or strictly nonblocking, depending on the number of middle switches and the scheduling method. Embodiments of rearrangeably nonblocking networks using $2*n$ or

more middle switches are described in the related U.S. Patent application, attorney docket No. M-12158 US that is incorporated by reference above.

In strictly nonblocking multicast networks, for any request to form a multicast connection from an inlet link to some set of outlet links, it is always possible to find a path through the network to satisfy the request without disturbing any existing multicast connections, and if more than one such path is available, any of them can be selected without being concerned about realization of future potential multicast connection requests. In wide-sense nonblocking multicast networks, it is again always possible to provide a connection path through the network to satisfy the request without disturbing other existing multicast connections, but in this case the path used to satisfy the connection request must be selected to maintain nonblocking connecting capability for future multicast connection requests. In strictly nonblocking networks and in wide-sense nonblocking networks, the switch hardware cost is increased but the time required to set up connections is reduced compared to rearrangeably nonblocking networks. The foregoing discussion relates to embodiments of strictly nonblocking networks where the connection set up time is reduced.

To provide the proof for the current invention, first the proof for the rearrangeably nonblocking behavior of symmetric networks $V(m,n,r)$ of the invention is presented. (Proof for rearrangeably nonblocking networks using $2*n$ or more middle switches is described in the related U.S. Patent application, attorney docket No. M-12158 US that is incorporated by reference above.) Later it will be extended for asymmetric networks $V(m,n_1,r_1,n_2,r_2)$. When $m >= 2*n$, the $V(m,n,r)$ Clos network is operated in rearrangeably nonblocking manner for multicast connections if the following scheduling criterion is met: Every connection request is fanned out at most twice in the input switch; Alternatively every connection request is set up through at most two middle switches.

Since when $m >= 2*n-1$, the $V(m,n,r)$ network is strictly nonblocking for unicast assignments, it means for unicast assignments, applicant notes that there always exists an available link through at least one middle switch from any arbitrary input switch to any arbitrary output switch. Alternatively, if there exists available links from an arbitrary input switch to a number of middle switches at least one of these middle

switches has an available link to any arbitrary output switch. It also means when $m >= 2*n-1$, from any arbitrary input switch if there exists available links to a number of middle switches, all output switches have available links from at least one of those middle switches.

To prove that the network is rearrangeably nonblocking for multicast assignments, applicant notes that it is necessary and sufficient to prove the following two conditions: 1) There are enough middle switches to fan out each connection at most twice in the input switch; 2) From an arbitrary input switch, there always exist at least two middle switches with available links between these two middle switches and the input switch such that there are available links to all the destination output switches, of any connection request (e.g. All output switches in case of a broadcast connection request), from these two middle switches.

To prove the condition 1, applicant observes that there are enough middle switches if each connection is fanned out at most twice since $m >= 2*n$. Moreover applicant provides proof for the condition 2 by contradiction as follows. In the worst-case scenario, suppose all the r output switches have $(n-1)$ outlet links already connected. Now suppose from the given input switch all the output switches have to be reached for the n th outlet link.

Suppose there are not at least two middle switches available through which there are available links from the given input switch to all the output switches. If it happens, then each of the middle switches will have $\left(\frac{r}{2}+1\right)$ second internal links already in use. i.e., total second internal links used in all the middle switches is given by,

$$\left(\frac{r}{2}+1\right)*(2*n)$$

$$= n*r+2*n$$

Which is not possible because the maximum possible second internal links in use is $n*r$.